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Local oscillator radiation from television receivers

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Summary

The local oscillator of a television receiver tuned to channel n can cause interference to a neighbouring receiver tuned to channel n + 5. If, in modern receivers, this radiation is significantly lower than that prescribed in British Standard BS 905:1969 consideration could be given to relaxing the planning standards in areas where the problem might arise.

This report examines the ways local oscillator interference becomes apparent and describes recent measurements made to determine whether there has been any reduction in the level of radiation from modern receivers. It concludes that there has been no significant reduction. Lower levels could probably be achieved by relatively simple design changes although it is thought that there is no particular incentive once the British Standard has been met.

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1. Introduction

Because of the ever increasing shortage of u.h.f. channels as the planning of new television relay stations progresses, it is important to explore every possibility which might result in more channels being released to the planners.

One such situation is the restriction which applies to transmitters which have overlapping service areas and operate on channels n and n + 5. For example, the local oscillator of a receiver tuned to channel n from a main station could cause interference to a neighbouring receiver tuned to channel n + 5 from a relay station. For this interference to be no worse than grade 2 on the EBU six-point impairment scale the present planning standards require that the field strength from the relay should be greater than 85 dB(μV/m). This assumes that all television receivers conform to British Standard BS 905:1969,[1] which states that local oscillator radiation from the chassis of a television receiver shall not exceed 70 dB(μV/m) at 3 metres and that the terminated voltage at the receiver aerial terminals shall not exceed 60 dB(μV).* Obviously if this level of radiation could be reduced then it would not be necessary to provide such a high field strength from the channel n + 5 transmitter.

With this in mind a short measurement programme was undertaken in which

i) the local oscillator radiation from a number of television receivers, some modern, some not so modern, was measured according to the method laid down in BS905 and

ii) a field strength survey vehicle was taken into an area where there existed an n + 5 channel relationship and the level of local oscillator radiation 'in the street' was observed.

2. Types of local oscillator interference

In any u.h.f. tuner there are two basic leakage paths where local oscillator radiation may escape. One is back through the r.f. stage or stages to the aerial socket where it ultimately appears at the aerial and is radiated according to the directional pattern of the aerial.

The other is general radiation from the receiver assembly, which is much more variable in amplitude, being dependent on the amount of screening employed and the presence or otherwise of any resonant lengths of chassis material.

2.1. Radiation via the aerial socket

The terminal voltage at the aerial socket is limited to 60 dB(μV) in BS 905 and is the source of any interference caused by direct aerial-to-aerial coupling.

This coupling can be considered in terms of the path loss between the terminals of the 'interfering' and 'interfered with' receivers. For aerials mounted on the same chimney stack this path loss, is on average, about 50 dB. (See Appendix I Section 1.)

For aerials mounted on different chimney stacks on opposite sides of the street, separated by about 15 metres, the path loss could be as low as 36 dB if they are pointing towards each other. (See Appendix I Section 2.) However, this is a relatively uncommon situation since it requires that both transmitters and both receiving aerials be on the same line. In any other location the directivity of the aerials will cause the path loss to be higher. (See Appendix I Section 2.)

Table 1 indicates the range of interference voltages which may be expected with aerial-to-aerial coupling. Also included in Table 1 is the resulting signal-to-interference ratio when the wanted field strength is 85 dB(μV/m). As a guide the CCIR recommend a protection ratio of 42 dB or more for interference from a c.w. signal 0.5 MHz below the wanted vision carrier to be just tolerable. The signal from a correctly tuned interfering receiver would fall into this category. For barely perceptible interference the protection ratio would have to be 10 dB to 15 dB higher.

The measurement of local-oscillator voltage at the aerial socket of a television receiver is

* In accordance with the British Standard convention all r.f. voltages are given in this report as the value across a terminating impedance of 75 ohms (rather than the unterminated voltage, which corresponds to e.m.f.).

TABLE 1

Maximum voltage likely to appear at the terminals of a television receiver as a result of local oscillator radiation from the aerial of a neighbouring installation

Aerial-to-aerial interference path	Path loss between respective receiver terminals, dB*	Resulting voltage at terminals of 'inter-fered with' receiver. (Assuming 60 dB(μV) at terminals of 'inter-fering' receivers)	Signal-to-interference ratio, dB, assuming a a wanted voltage of 68 dB(μV)**
Aerials on same chimney stack with approx. 1 metre spacing	50	10	58
Aerials on separate stacks about 15 metres apart looking towards each other	36	24	44
As above but looking away from each other i.e. neither within 60° of beam axis of the other	66	−6	74

* See Appendix I, Sections 1 and 2 for path loss calculations.

** Assumes a wanted field strength of 85 dB(μV/m) and an aerial system K factor of 17 dB. See Appendix I, Section 3 for K factor derivation.

covered in Research Department Report No. 1972/4,[2] where it is stated that of the receivers tested none exceeded the BS905 limit of 60 dB(μV) although some came close to it. However, it will be shown in Section 2.2 that interference is more likely to be caused by radiation from the chassis of a receiver than from its aerial system. Later on in Section 4 this conclusion is reached again as a result of measurements made in a residential area.

2.2. Chassis radiation

There are two situations where interference due to chassis radiation can be troublesome. One is in semi-detached or terraced housing where the two receivers are positioned either side of an adjoining wall, perhaps only 1.5 metres or so apart. If the interfering receiver is radiating the maximum allowable under BS905, i.e. 70 dB(μV/m) at 3 metres, the field strength at 1.5 metres will be 76 dB(μV/m). Assuming that the adjoining wall introduces an attenuation of 6 dB (the value assumed in previous work on this subject), then the receiver on the opposite side of the wall will be immersed in a field of about 70 dB(μV/m). It can be shown that this is equivalent to a voltage at the receiver input terminals of 22 dB(μV). (See Appendix I, Section 4).

The other situation is where the two receivers are separated by a much greater distance, say 15 metres, i.e. on opposite sides of the road. Here the interference path lies between the chassis of the 'interfering' receiver and the aerial of the 'interfered with' receiver. Taking the worst case, with the chassis radiation at its maximum value and the receiving aerial pointing at the source of interference, the voltage appearing at the terminals of the 'interfered with' receiver would be around 21 dB(μV). (See Appendix I, Section 5). Of course if the aerial were pointing away from the interfering chassis (60° or more off-axis) then a further 5 dB of protection would be provided, bringing the voltage at the receiver terminals down to 16 dB(μV). Table 2 summarizes the results for chassis radiation.

From Tables 1 and 2 it can be seen that, for adjacent installations, interference is more likely

TABLE 2

Maximum voltage likely to appear at the aerial terminals of a television receiver as a result of radiation from the chassis of a neighbouring receiver

Interference path	Voltage, dB(μV), at terminals of 'interfered with' receiver*	Signal-to-interference ratio, dB, assuming a wanted voltage of 68 dB(μV), i.e. a field strength of 85 dB(μV/m))
Chassis to chassis (receivers on opposite sides of adjoining wall with approx. 1.5 m separation)	22	46
Chassis to aerial (Approximately 15 m separation)	21 to 16 (Depending on aerial orientation)	47 to 54 (Depending on aerial orientation)

* See Appendix I, Sections 4 and 5.

to be caused by direct chassis-to-chassis coupling than by aerial coupling.

Where the separation is much greater, interference from the chassis and from the aerial become comparable but, since chassis radiation is more omni-directional than that from the aerial, the former is more likely to be the main cause of interference.

3. Measurement of the local oscillator radiation from seven commercial receivers

As mentioned in Section 2.1 the measurement of the local oscillator voltage appearing at the aerial socket has already been covered,[2] so that it only remains to investigate the radiation from the receiver chassis.

The method for doing this is laid down in BS905 and involved the construction of a special test-jig over a wire mesh earth mat. The receiver under test was placed at a set height above the ground and connected to a vertical length of feeder which was terminated in a 75Ω resistor. The measuring aerial was a broad-band dipole mounted 3 metres away from the tuner of the television receiver and was moved in a vertical plane from ground level to 4 metres to obtain maximum pick-up of oscillator radiation at each frequency investigated. The field strength meter was a standard Research Department measuring receiver.

Seven different television receivers were measured, three of which were over ten years old, the remaining four being manufactured within the last five years. Fig. 1 shows the field strength variation with frequency (the frequency to which the television receiver is tuned and not that of its local oscillator). The approximate dates of manufacture are also given. With the exception of receiver C all the sets had transistor tuners.

4. Measurement and observation of local oscillator radiation in an n + 5 service area overlap

Careful frequency planning has resulted in a marked absence of local oscillator interference problems. However, this is not to say that overlapping service areas with an n + 5 channel relationship do not exist.

Take for example the Scottish coastal town of Largs 40 km west of Glasgow, which until the recent opening of the Rothesay relay station, was marginally served from Divis (Northern Ireland) and no other station. Viewers unable to pick up Divis satisfactorily could receive the preferred Scottish programmes via the local wire service. However, when Rothesay became operational many of these viewers had aerials installed to watch their programmes 'off-air'. In theory this should cause problems to the existing Divis viewers since the local oscillator of a new Rothesay receiver tuned to channel 22 (BBC-1) could cause interference to a nearby Divis viewer watching

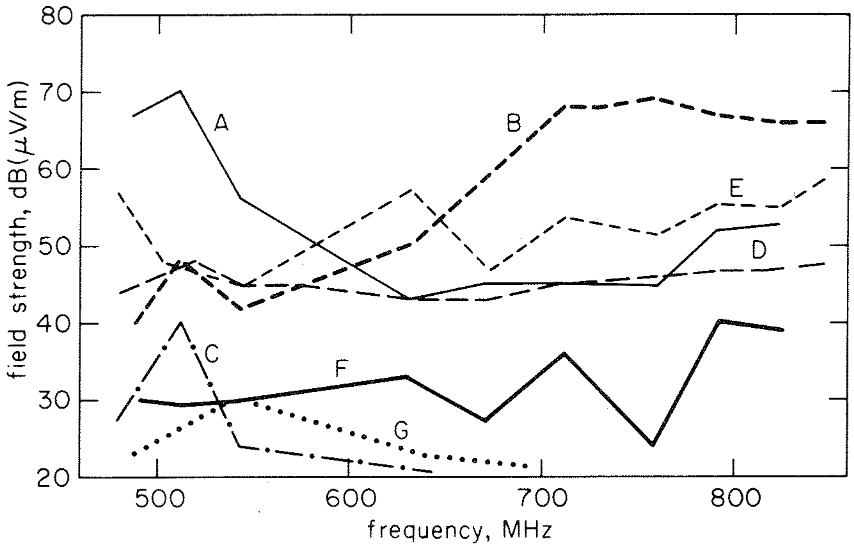

Fig. 1 - Field strength at 3 metres from seven commercial television receivers tuned to channel n, (the field strength being measured on channel n + 5)

Receiver	Year of manufacture	
A	1965	
B	1965	
C	1965	
D	1972	
E	1973	
F	1973	
G	1975	

channel 27 (BBC-2). In practice the problem seldom exists since, by following the advice of local dealers, the Divis viewer has only to retune to Rothesay to obtain an interference free picture, in most cases without even realigning his aerial.

With the aim of observing local oscillator interference and measuring the radiation levels in a typical suburban area, a Research Department field strength survey vehicle was taken to Largs equipped with a spectrum analyser, a television receiver and a log-periodic aerial fitted with a pre-amplifier. The minimum field strength which this equipment could measure was about 24 dB(μV/m).

An initial cruise through the streets of Largs in the early evening indicated an abundance of local-oscillator radiation. This was observable directly on the spectrum analyser and indirectly as an interference pattern on the television receiver, which had been tuned to Divis channel 27.

When observing a particular source of radiation the aerial was adjusted in height and azimuth to determine whether the signal was coming from the television receiver itself or from its aerial. In doing this it was necessary to choose a street which was normal to the transmitter/viewer propagation path so that the measuring apparatus would be in the main lobe of the domestic receiving aerial.

In general, the measurements indicated the receiver chassis to be the source of greatest radiation. In fact, by estimating the distance to the receiver and noting the field strength it was possible by simple extrapolation, to arrive at an approximate value for the field strength at 3 metres, thus giving an indication of how the receivers complied with BS905. In terms of this 3-metre value typical field strengths were of the order of 60 to 65 dB(μV/m), (see Table 3).

In terms of picture degradation, the on-board television receiver interference was invariably grade 6 on the EBU six point impairment scale, but this was hardly surprising since the 'wanted' field strength from Divis was only 55 dB(μV/m).

It would have been interesting to obtain

TABLE 3

Typical field strengths resulting from local oscillator radiation measured in Largs

Maximum measured field strength from interfering television receiver dB(μV/m)	Estimated distance from interfering receiver (metres)	Estimated field strength at 3 metres dB(μV/m)
39	25	63
40	15	60
41	15	61
41	25	65
47	15	67

details about the receivers under observation i.e. type, age etc., but consternation amongst the viewing population caused by a procedure similar to checks for licence evasion was sufficient to preclude a detailed investigation.

5. Conclusions

From an initial analysis it appeared that radiation from the receiver chassis was likely to be more troublesome than that coming from the aerial, assuming of course that receiver radiation approaches the maximum allowed under BS905. Consequently chassis radiation became the subject of the main assessment.

Measurements of chassis radiation made at Research Department on a number of commercial receivers indicated a wide variation in level both from set to set and across the band. Although the two sets (A and B) which actually reached the 70 dB(μV/m) limit at certain frequencies were about 12 years old, they were fitted with transistor tuners.

In a residential area where many viewers had recently changed from a wire service to a new relay station (with the resultant probability of there being a higher than normal number of new sets) measurements in the streets indicated that there were many sets with estimated 3-metre radiation figures of at least 60 dB(μV/m).

It is therefore reasonable to assume that transistor tuners have not resulted in greatly reduced levels of local oscillator radiation and that so long as the 3 metre limit remains at 70 dB (μV/m) there will always be some receivers with radiation figures approaching this value which, according to Table 2, can cause grade 3 interference to receivers 1.5 metres apart separated by a party wall. Hence, whilst the current British Standard remains, it would be inadvisable to alter the planning requirement that the wanted field strength in an n + 5 overlap area be 85 dB(μV/m) or more.

If the limit for the radiation at 3 metres were reduced to 40 dB(μV/m) which, according to Fig. 1, appears to be an obtainable value, together with a similar reduction for the voltage at the aerial terminals, then ultimately the problem of local oscillator interference would vanish, but a period of 10 years or so would have to elapse to allow those present day receivers with high radiation figures to become obsolete, by which time it would be too late.

6. References

1. British Standard 905:1969. Specification for Radio Interference Limits and Measurements for Television and VHF Sound Receivers.

2. REED, G.R.C. Interference characteristics of dual-standard monochrome television receivers operating in the u.h.f. bands. BBC Research Department Report No. 1972/4.

3. SPENCER, J.G. UHF television: interference caused by a receiver operating on channel n to an adjacent receiver tuned to channel n + 4. BBC Research Department Report No. 1970/9.

4. SPENCER, J.G. Local-oscillator interference with u.h.f. television reception. BBC Research Department Report No. G-093, Serial No. 1964/32.

Appendix I

The following derivations refer to the figures quoted in Tables 1 and 2

1. Aerial-to-aerial interference where the aerials are closely spaced (about 1 metre), i.e. mounted on the same chimney stack

Theoretical calculations in the near field regions of aerials are invariably complicated and of doubtful accuracy. Previous work on the subject[4] has indicated that the path loss between two closely spaced domestic aerial systems is about 50 dB. 15 years have elapsed since then and it was thought that further work would be relevant at this stage. A brief experiment was therefore conducted to investigate the insertion loss between two close-mounted receiving systems.

Two Antiference TC-13 domestic receiving aerials were erected at a height of 10 metres above flat ground. They were mounted such that their relative positions and spacings could be adjusted to simulate the situations which arise with adjacent dwellings. 15 metres of 75Ω feeder was connected to each aerial, the insertion loss being measured between the lower ends of these feeders. Four basic configurations were used:—

(a) Horizontally spaced by 1 metre, initially side by side pointing in the same direction, then one aerial rotated horizontally in 45° steps through 180°.

(b) As in (a) but initially in line pointing in the same direction.

(c) Vertically spaced by 1 metre, initially both pointing in the same direction then one aerial rotated horizontally in 45° steps through 180°.

(d) As in (c) but with 0.5 metre spacing.

Measurements were made with both aerials horizontally polarized, then vertically polarized and finally with the aerials cross-polarized. The frequency used was 660 MHz. The values of insertion loss were corrected to correspond to the case where each feeder has an attenuation of

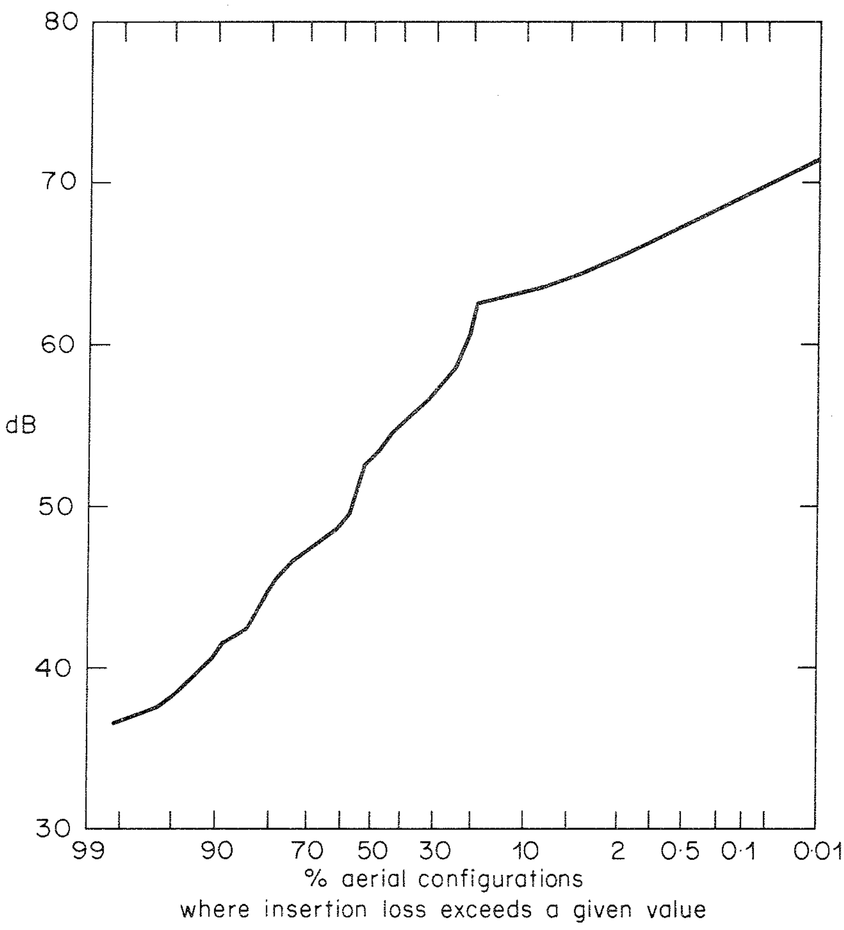

Fig. 2 - Distribution of insertion loss

4 dB. (The value assumed throughout this report).

Fig. 2 shows how the results are distributed. The mean value comes to 52 dB and Fig. 2 indicates that at least 80% of the aerial configurations used had values greater than 45 dB. Consequently these new measurements give no reason for changing from the previously adopted figure of 50 dB.

2. Aerial-to-aerial interference where the aerials are spaced by about 15 metres, e.g. one installation across the street from the other

With the aerial separation large compared with a wavelength it becomes feasible to use standard path loss calculation techniques and, ignoring phase and amplitude of any reflections, an approximate overall path loss is given by:

$$L = L_I - 2G_\lambda - G_T - G_R + L_T + L_R \qquad (1)$$

where L_I the path loss between two isotropic sources =

$$20 \log \frac{4\pi d}{\lambda}$$

G_λ the gain of a half-wave dipole relative to an isotropic source = 2.14 dB.

G_T and G_R are the gains of the two aerials relative to a half-wave dipole. 10 dB is taken as a typical figure.

L_T and L_R are the associated feeder losses and 4 dB is taken as being typical.

Using a mid-band frequency of 660 MHz Equation (1) becomes

$$L = 52.4 - 4.3 - 10 - 10 + 4 + 4$$

$$L = 36 \text{ dB}$$

Hence with a voltage at the terminals of the interfering receiver of 60 dB(μV) the resulting voltage at the terminals of the interfered-with receiver will be 24 dB(μV). This is for the situation where aerials with the same polarization are firing towards each other.

The other extreme would be for co- or cross-polarized aerials looking away from each other. Existing Service Planning standards state that the protection afforded by each aerial would be 15 dB, thus the maximum path loss would be about 66 dB.

$$\text{i.e.} \quad L = 36 + 15 + 15 = 66 \text{ dB}.$$

3. The K factor of a typical domestic receiving installation

The term K factor is assumed to be the difference in dB when the terminated voltage at the receiver input is subtracted from the field strength at the aerial.

For a 75Ω system it is given by:

$$K = L_R - G_R - 20 \log \frac{\lambda}{\pi} + 6$$

Hence for a typical domestic installation operating on a mid-band frequency of 660 MHz,

$$K = 4 - 10 - (-17) + 6$$

$$= 17$$

If the field-strength at the aerial was 85 dB (μV/m) then the voltage at the receiver terminals would be 68 dB(μV/m).

4. Chassis-to-chassis interference, i.e. receiving installations on opposite sides of a party wall

Interference arising in this situation is a function of the receiver's immunity to direct pick-up. According to BS905, immunity is defined as the ratio in dB of E_1 to E_2 where

E_1 is the field strength in dB(μV/m) required to produce a given output from the receiver when it is connected to a length of terminated feeder and

E_2 is the field strength in dB(μV/m) required at a half-wave dipole connected to the same receiver via the same feeder to produce the same output, when the receiver and feeder are placed in a perfectly screened enclosure.

BS905 specifies limits for immunity of 30 dB in Band IV (470 – 582 MHz) and 25 dB in Band V (614 – 960 MHz). Here, the latter figure is taken as being representative for the whole u.h.f. band

$$\text{i.e.} \quad E_1 - E_2 = 25 \text{ dB} \qquad (2)$$

If V is the terminated voltage at the receiver input socket resulting from the field strength E_2 and if a dipole is assumed together with a connecting feeder of negligible loss then, for a mid-band frequency of 660 MHz (i.e. $-20 \log \lambda/\pi = 17$ dB),

$$E_2 - V = 17 + 6 = 23 \text{ dB} \quad (3)$$

combining (2) and (3)

$$V = E_1 - 48$$

This implies that the interference produced by immersing the receiver in a field of E_1 dB (μV/m) is the same as that produced by a voltage at the receiver input terminals of E_1 – 48 dB (μV).*

Returning to the above situation, if it is assumed that the interfering receiver is radiating a field-strength of 70 dB(μV/m) at 3 metres and if the wall is assumed to contribute an attenuation of 6 dB, then the 'interfered with' receiver, if placed on the other side of the wall at a distance of about 1.5 metres from the first receiver, will be immersed in a field of 70 dB(μV/m). This is equivalent to a voltage at its input terminals of 22 dB(μV).

* It is assumed that the receiver is terminated with a 75Ω resistor, or if an aerial and feeder are connected, that there is negligible pick-up from the aerial because of its vertical radiation pattern (v.r.p.) and remote position.

5. Chassis-to-aerial interference where the installations are across the street from each other and separated by about 15 metres

If the aerial height is assumed to be about 10 metres and the interfering receiver is assumed to be on a ground floor then the path length involved will be 18 metres and the free-space field-strength at the aerial from a source which radiates 70 dB (μV/m) at 3 metres is given by

$$E = 70 - 20 \log \frac{18}{3}$$

$$= 54 \text{ dB}(\mu\text{V/m})$$

This would be reduced by about 6 dB due to the wall of the house. For an aerial gain of 10 dB, a feeder loss of 4 dB and a mid-band frequency of 660 MHz the aerial system K factor would be 17 dB resulting in a voltage at the receiver input of 31 dB(μV).

However a further reduction in signal of about 10 dB is provided by the v.r.p. of the aerial assuming that the main lobe of the h.r.p. is in the direction of the interference. This would result in a voltage of 21 dB(μV).

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